Ground Validation Assessments of GPM Core Observatory Science Requirements

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Outline

- "Level-1" Science Requirements
- Data
- Rain rate
- DSD
- Demonstrating Snow Detection
- Summary

Acknowledgements:
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GPM "Core" Satellite Science Requirements

(Termed "Level -1" or "L1")

- DPR: *quantify rain rates* between 0.22 and 110 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 5 km*.

- GMI: *quantify rain rates* between 0.22 and 60 mm hr-1 and *demonstrate the detection of snowfall* at an *effective resolution of 15 km*.

- Core observatory radar estimation of the Drop Size Distribution (DSD)- specifically, D_m *to within +/- 0.5 mm*.

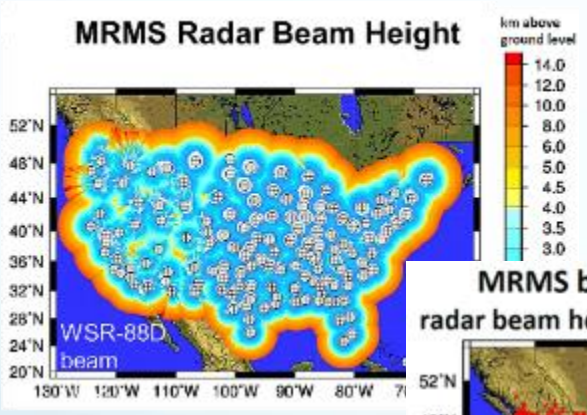
- At 50 km resolution, space-based *instantaneous* rain rate estimate with *bias and random error < 50% at 1 mm* hr^{-1} *and < 25% at 10 mm* hr^{-1}*, relative to calibrated GV*

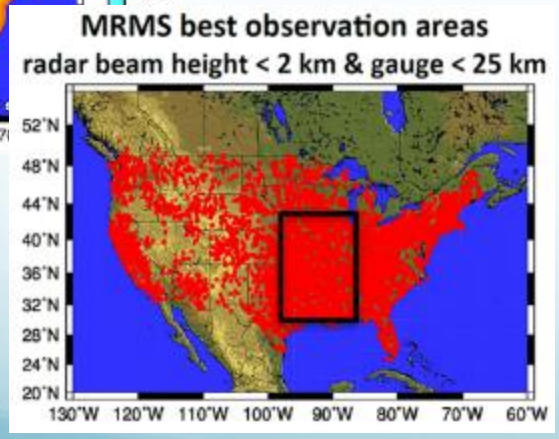
Data

http://gpm-gv.gsfc.nasa.gov/

1) NOAA Multi-Radar Multi-Sensor (MRMS) Precipitation Rates

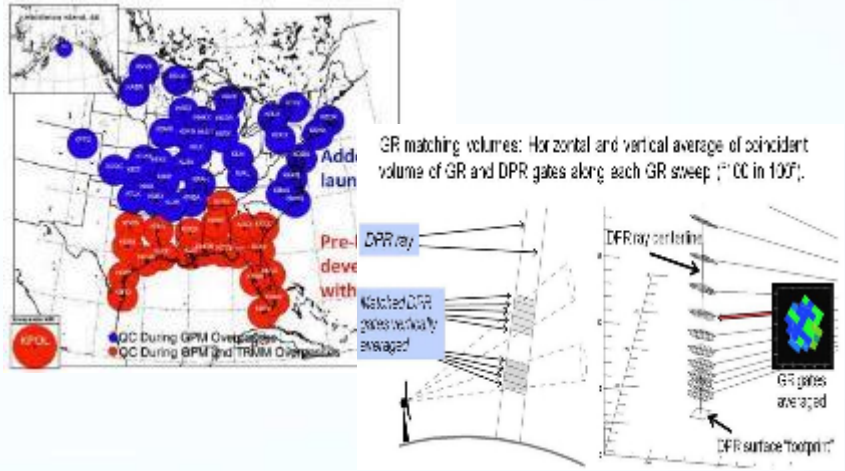
- Gauge bias-corrected radar estimates of precip ***rate and type***
- 0.01º / 2 minute resolution
- Quality-constrained "reference" subsets created





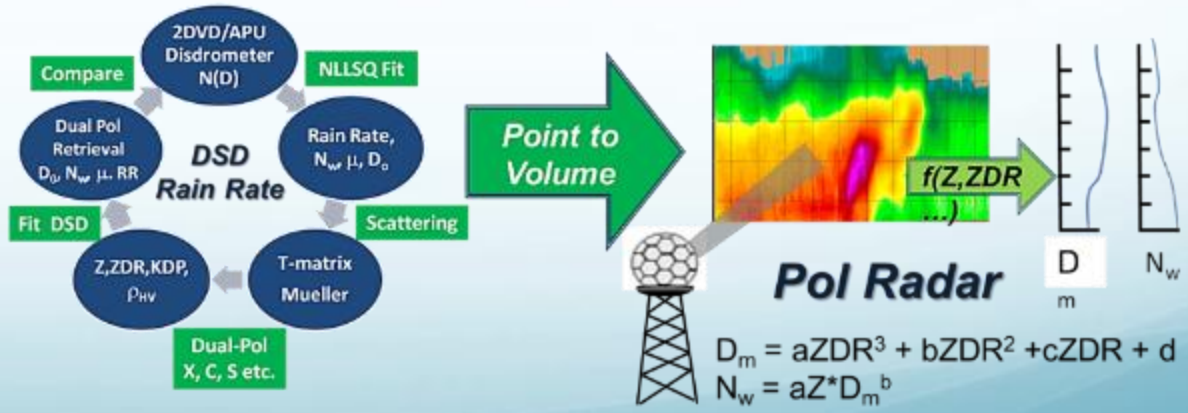
2) Validation Network

- QC'd 3-D radar volumes and variables geo-matched to DPR sample volumes and GMI footprints
- 65 US + numerous research and international radars



3) Field site observations

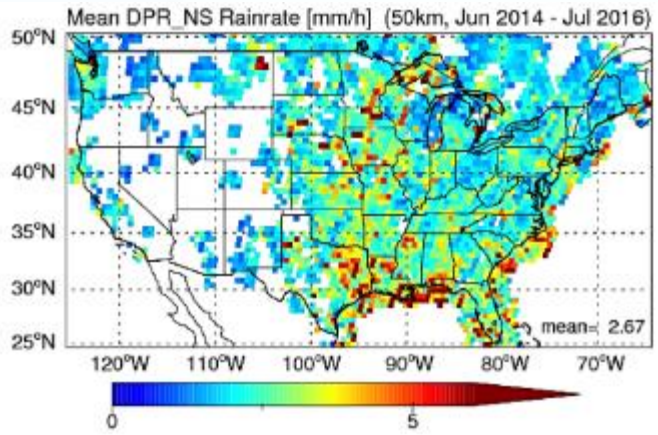
- Disdrometer, Radar, Dense Gauge network

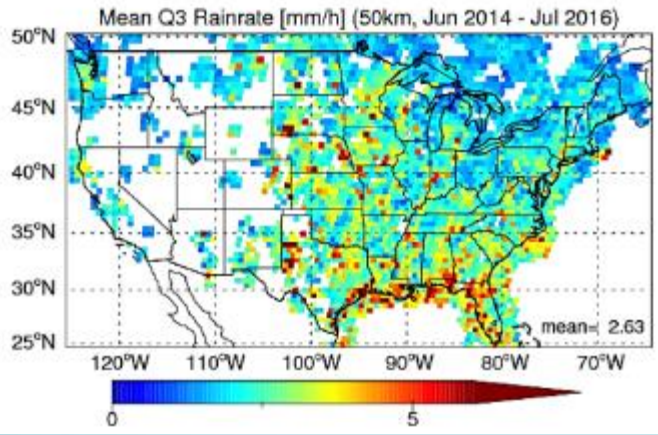


Rain: General Continental Context (50 x 50 km)

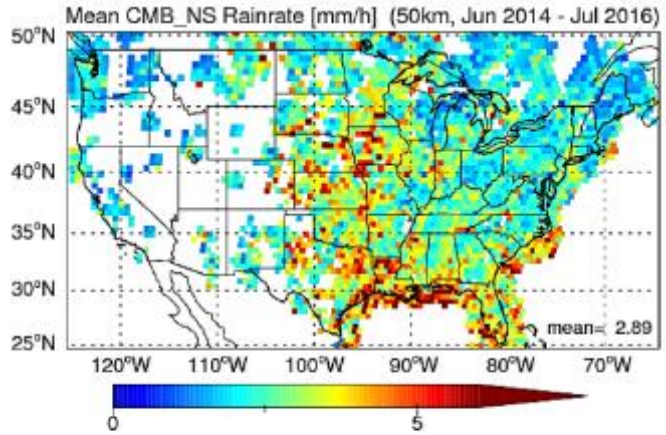
CONUS June 14 – July 16: GV MRMS vs. DPR, Combined, and GMI GPROF
Conditioned on 0.2 mm/hr threshold at FOV

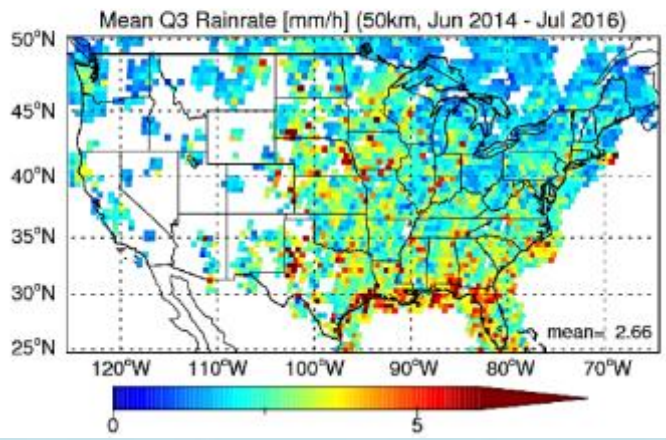
DPR



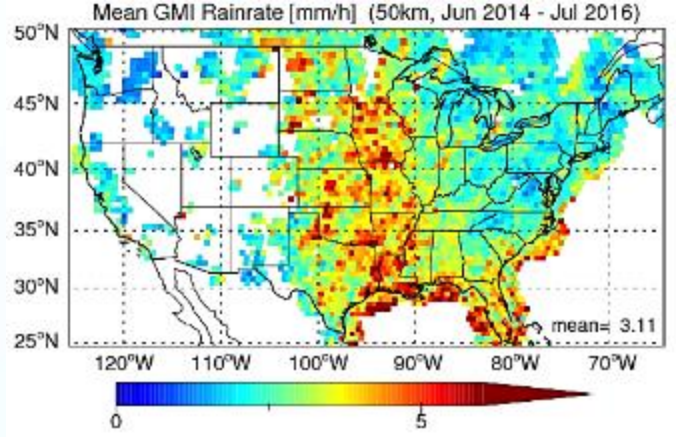


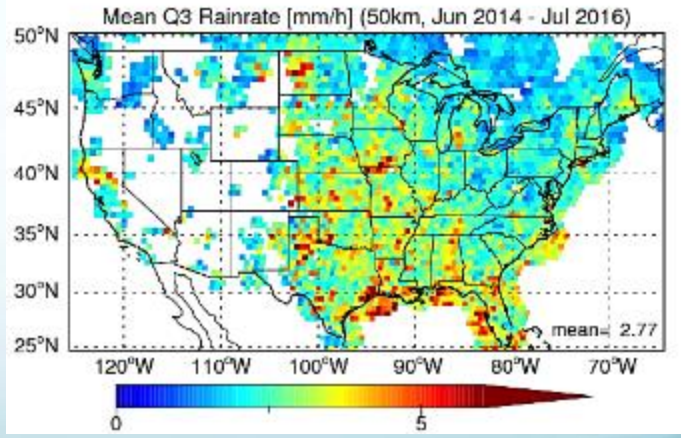
Combined





GPROF GMI



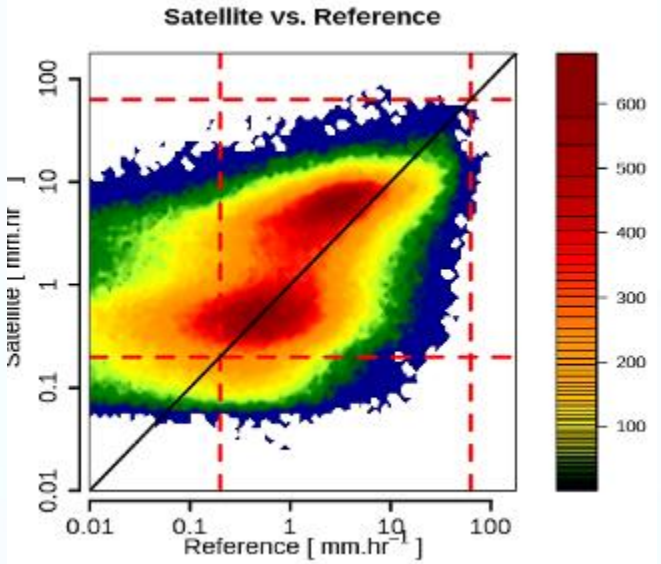


- Check to product to product variability- e.g., V5 DPR products all in good agreement with GV (similar to V4)
- Radar products in better agreement with MRMS; GPROF estimate in "MCS alley" still a little high.

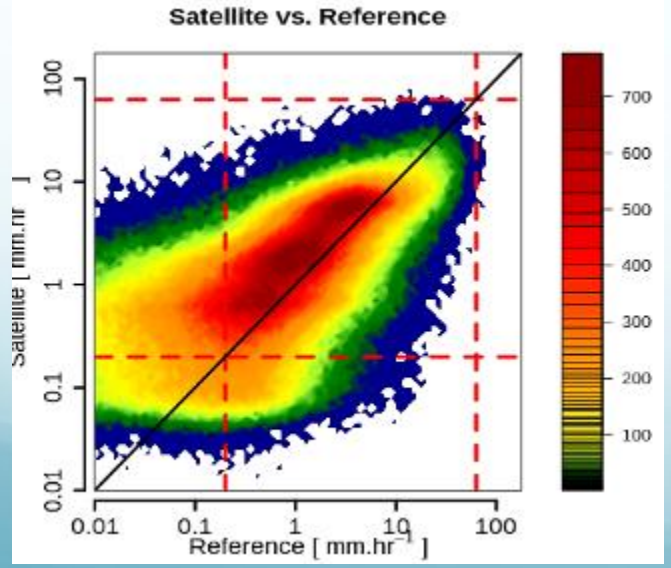
V4 and V5 GPROF GMI, and L1 **Rain Rate** vs. GV MRMS

Footprint (15 km)

V4

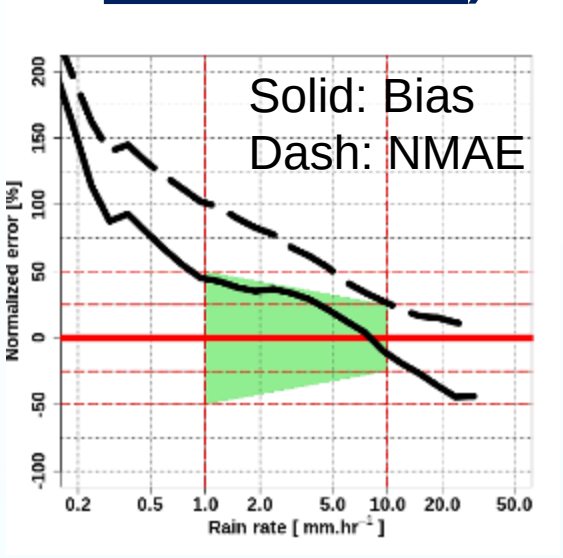


V5

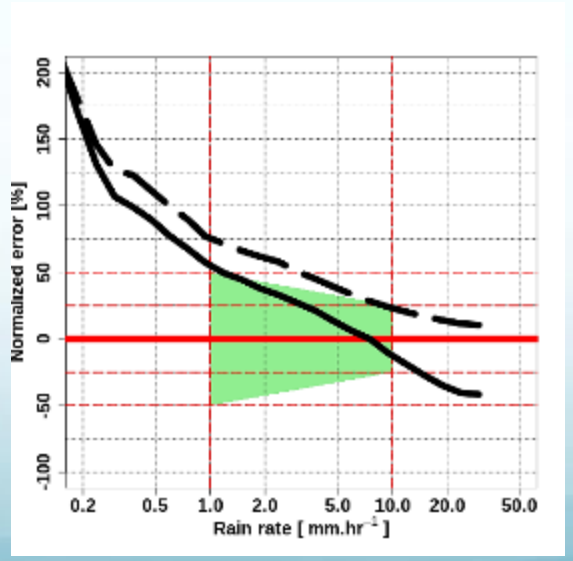


Level 1 (50 km)

V4



V5



V4

Footprint:

Correlation 0.47, bias 24.6%- non-uniform and with modes;

L1:

Footprint:

- Range of 0.2 - 60 mm/hr ✓
- 50 x 50 km ✓
- Bias
- Random error (NMAE) X

V5

Footprint:

Correlation 0.57, bias 20 %;

Smoother bias, reduced NMAE; greater extension to light rain;

L1:

Footprint:

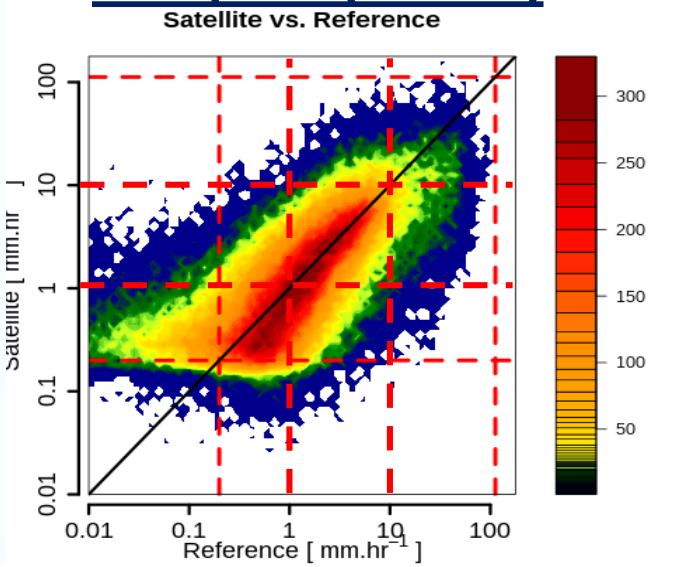
50x50km

- Bias: (better) ✓
- NMAE: (still a bit high) X

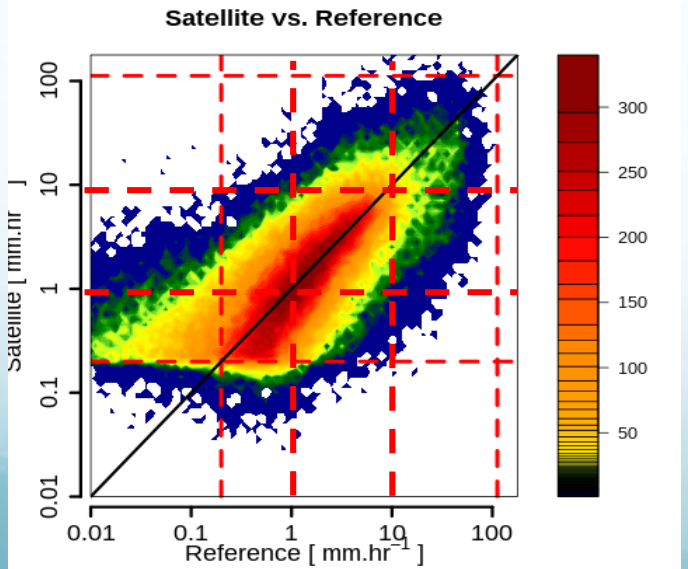
V4 and V5 **DPR MS**, and L1 **Rain Rate** vs. GV MRMS

Footprint (~ 5 km)

V4

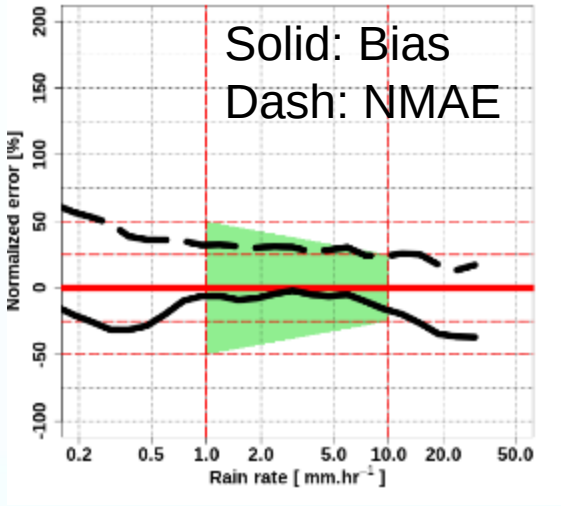


V5

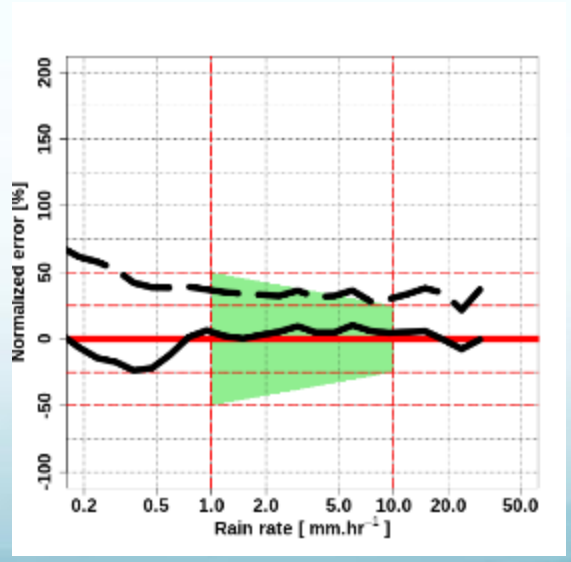


Level 1 (50 km)

V4



V5



V4 ok, V5 better!

- V5 Conditional bias < 12%

<u>L1:</u>

Footprint:

0.2-110* mm/hr

(*sample numbers at >100 mm/hr; < 0.01%)

50 x 50 km

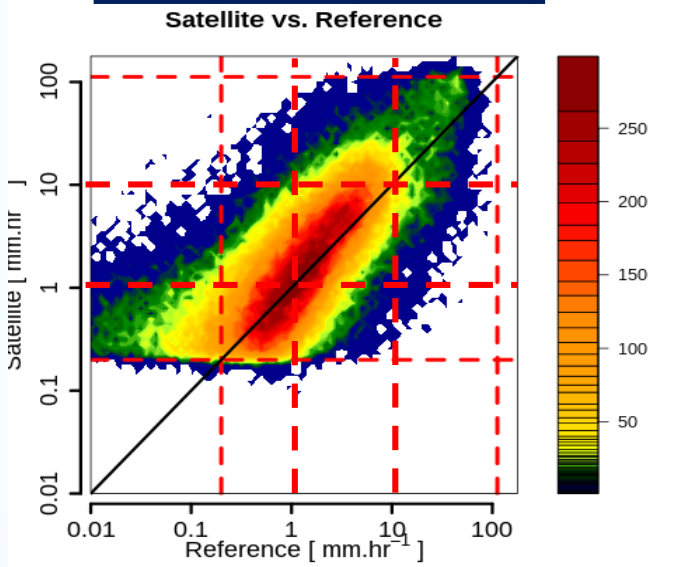
Bias

NMAE (improved V5)

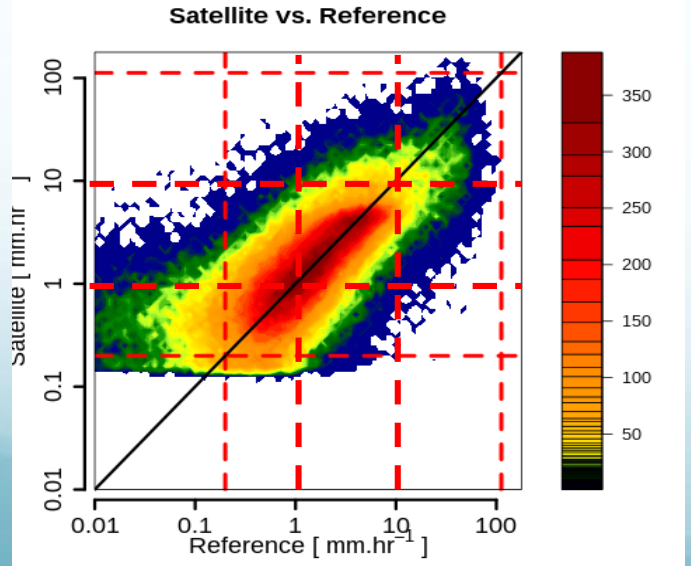
V4 and V5 **Combined Alg. MS**: **Rain Rate** vs. GV MRMS

Footprint (~ 5 km)

V4

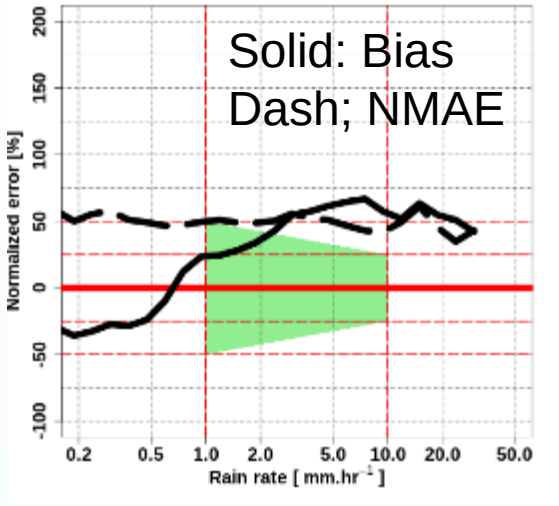


V5

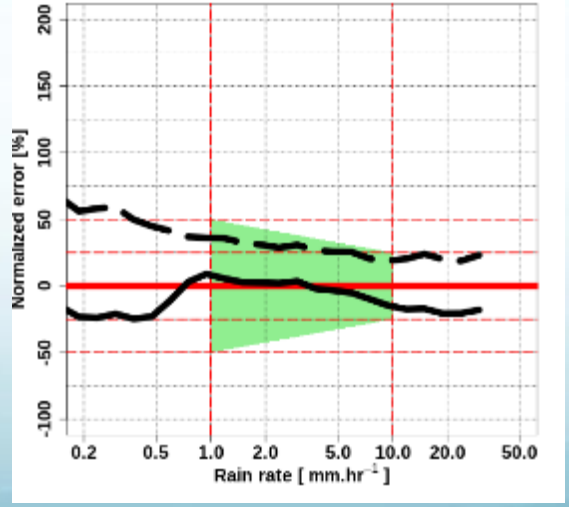


Level 1 (50 km)

V4



V5



Relative to V4 (top; had known issues), V5 (bottom) is **MUCH** improved!

Conditional bias for V5 at footprint scale < 1% for V5

L1

Footprint:

0.2-110 mm/hr ✓

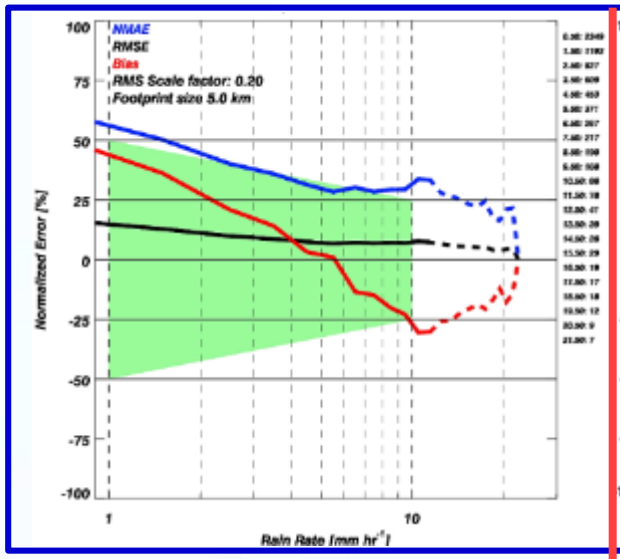
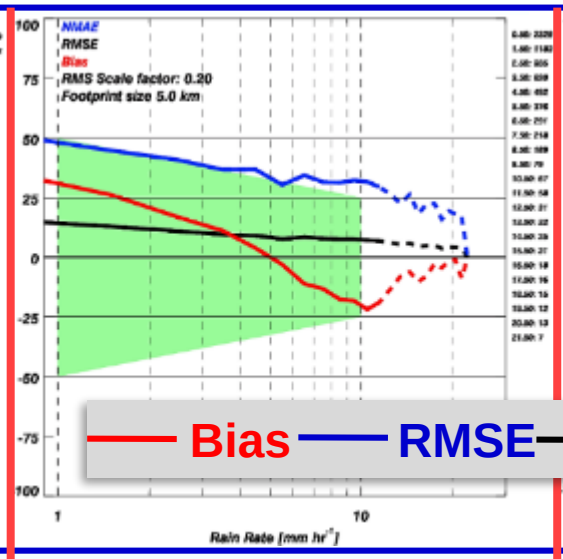
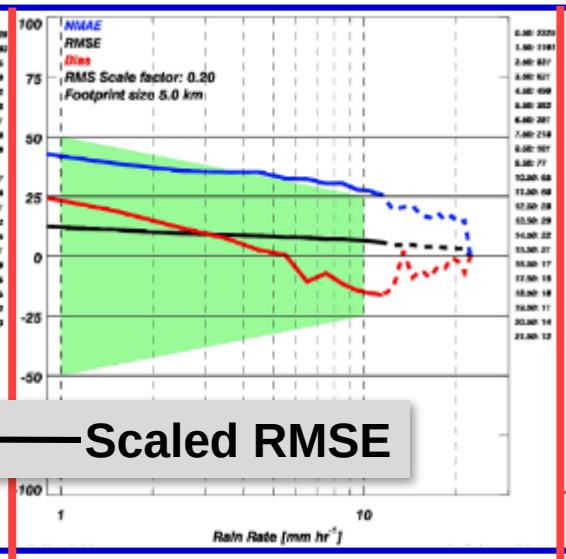
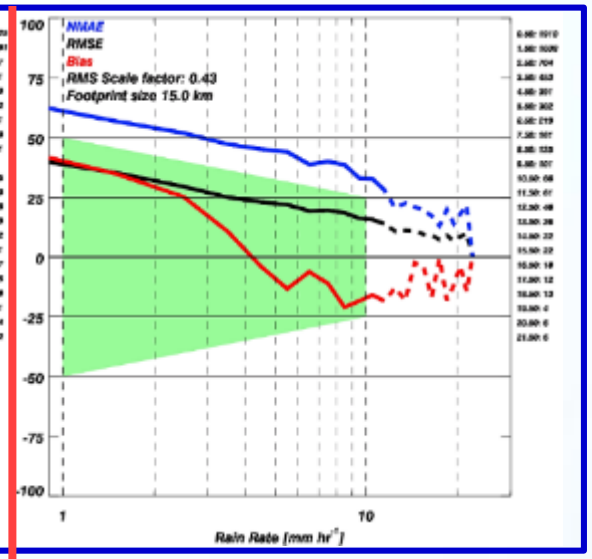
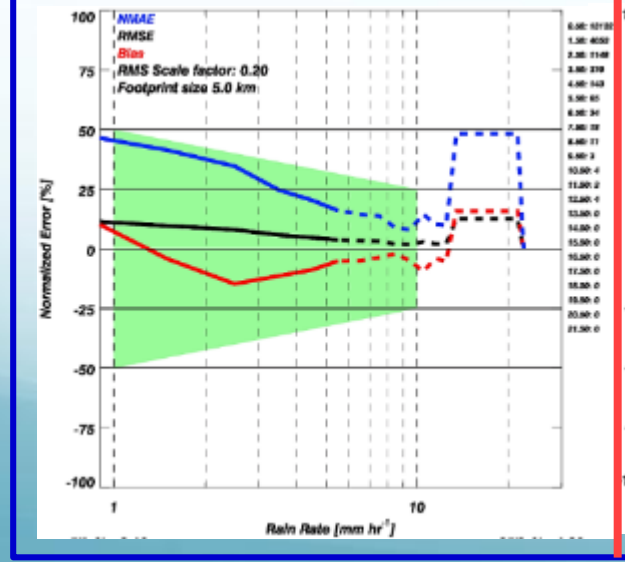
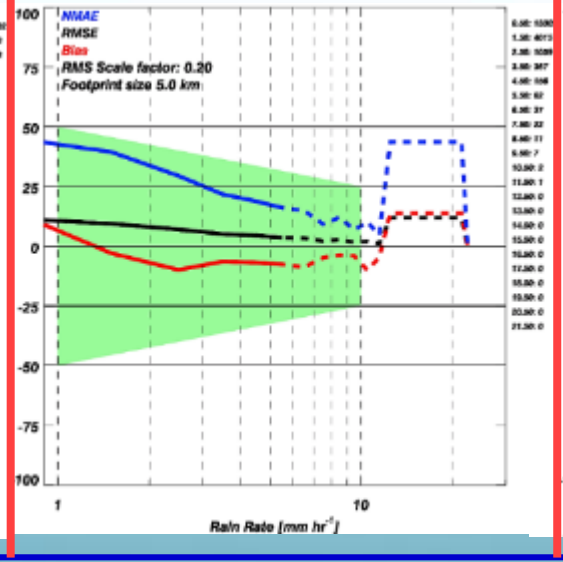
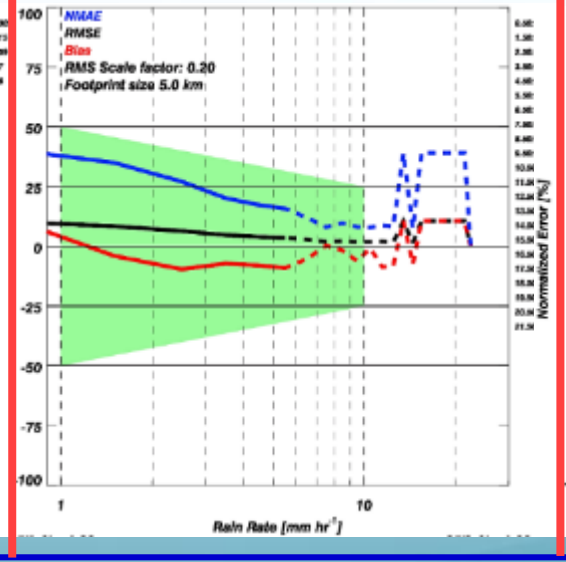
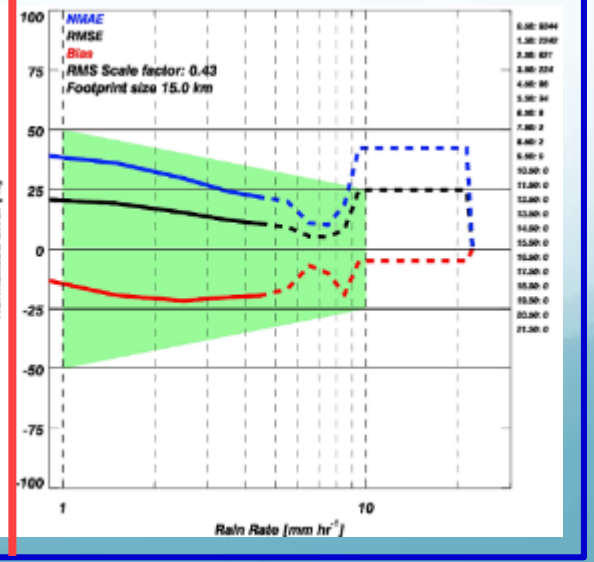
50 x 50 km

Bias ✓

NMAE ✓

Ocean Radar (PAIH and KWAJ) **Footprint (L1 proxy) Rain Rates** V5

L1 requirements met (similar behavior to V4 with sporadic improvement)
Sensitivity to regime, beam filling and footprint size

	CMB NS	DPR NS	2AKu	GPROF-GMI
KWAJ (8°N)				
PAIH (60° N)				

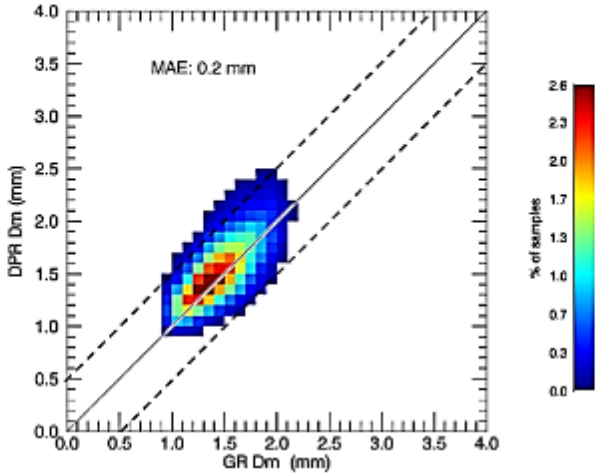
DPR MS V4, V5 vs. GV Radar D_m

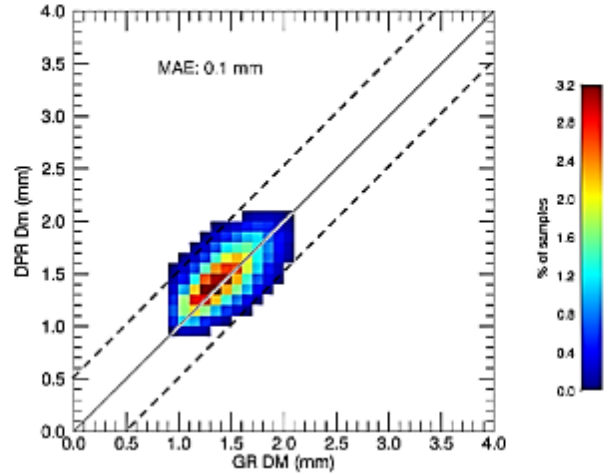
All Samples

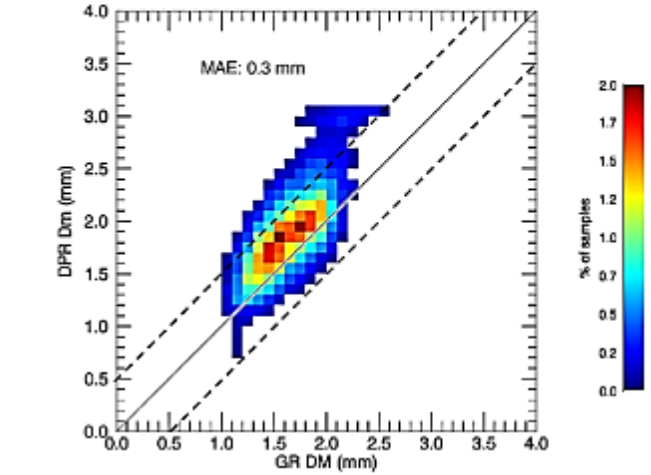
Stratiform

Convective

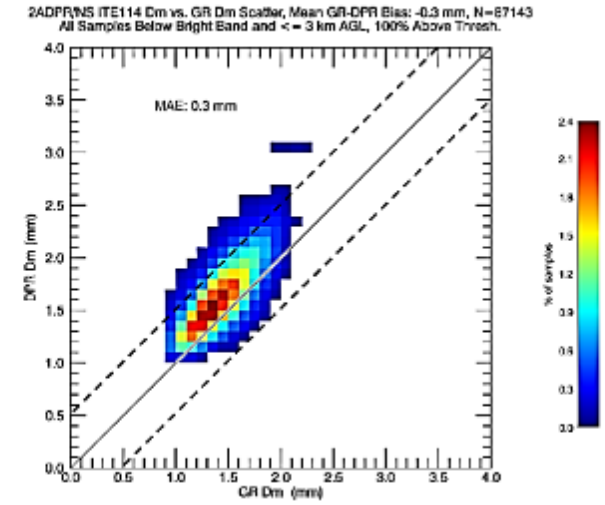
V4

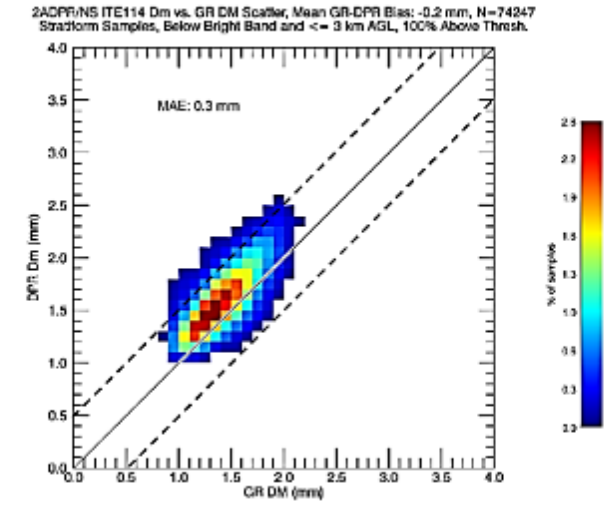


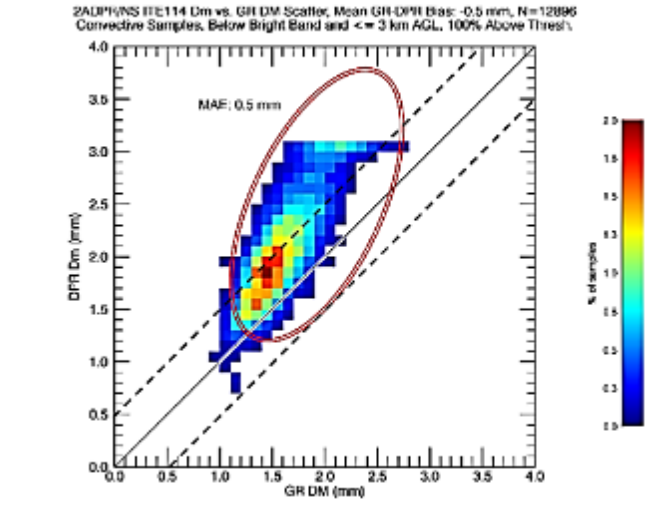




V5



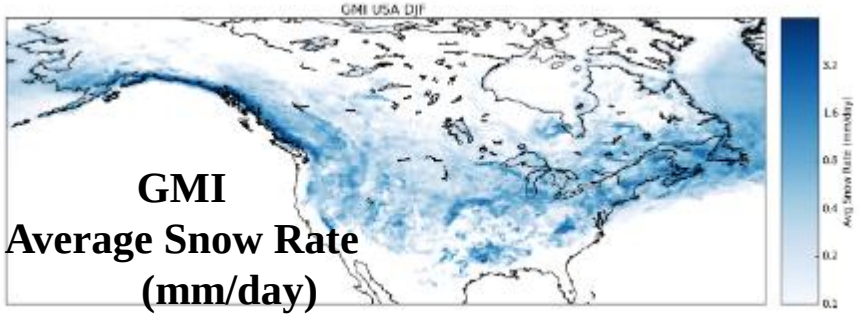




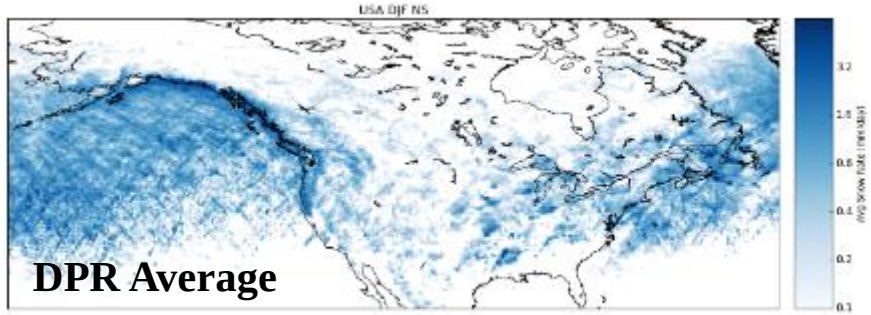
L1: Within limits…But..V5 Positive bias in D_m relative to GV; Convective deviates more from V4 (large Dm mode?)

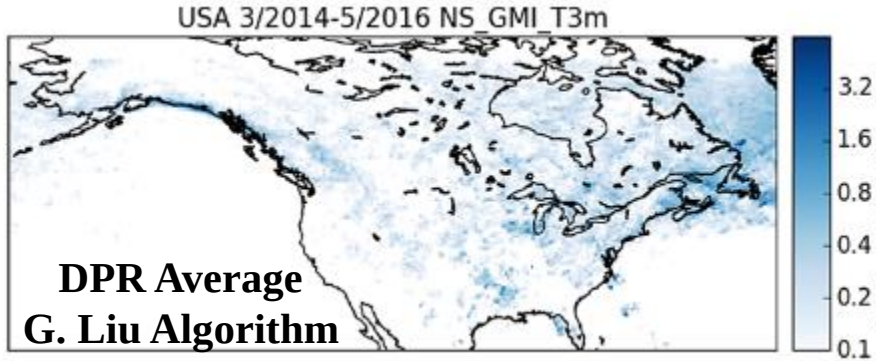
SNOW: "Demonstrate *Detection*" ……

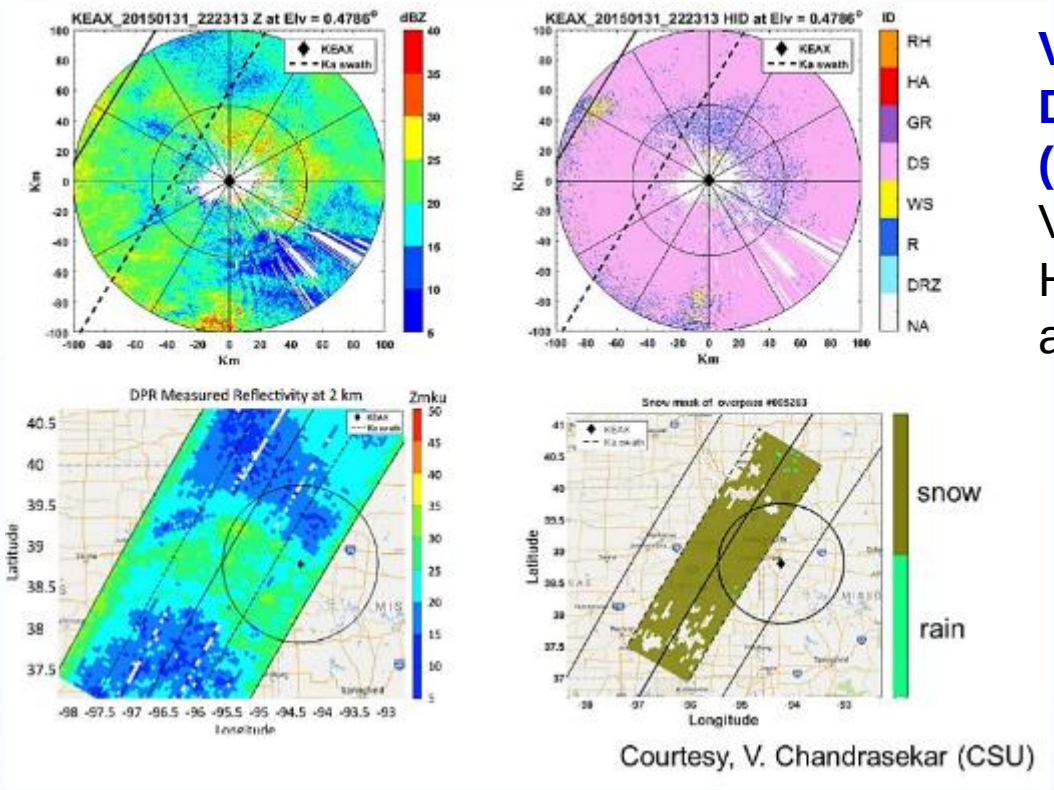
GMI



DPR







Version 5: New DFRm snow-Index (Le and Chandra):
Validation using 88D HID algorithms against DPR MS

This essentially demonstrates detection and satisfies requirements but……difference in algorithms related to assignment of snow at/near the surface.

Quantifying Snow "Detection" and Rain-Snow "Delineation"

MRMS "reference" data. Heidke Skill Score (HSS) used to balance hits, misses, false alarms, correct rejects.

Delineation: MRMS determines "type" (rain or snow). HSS maximized against the reference type.

Detection: HSS maximized for the satellite as a function of MRMS snow water equivalent rate (SWER); the "detection" threshold then corresponds to the SWER at the inflection point of the HSS curve.

Product	Detection HSS / Threshold	Delineation HSS
GMI GPROF*	0.43 / 0.63 mm hr^{-1}	0.77
DPR MS	0.49 / 0.58 mm hr^{-1}	0.66
CMB MS	0.57 / 0.63 mm hr^{-1}	0.67
DPR NS	0.43 / 0.58 mm hr^{-1}	0.65
KuPR	0.44 / 0.58 mm hr^{-1}	0.65

* Need to include snow/ice-covered surfaces when doing the statistics

- Detection threshold ~ 0.5-0.7 mm/hr for radar and radiometer consistent with theory and previous observational comparisons to gauges in U.S. (at least for radar)
- Radar product HSS for delineating rain/snow *at* the surface a bit lower than radiometer

Summary

- GPM must meet "Level 1" science requirements for GPM Core Satellite products: footprint to 50 km scales, rain rate, DSD (hard requirement on D_m), and for demonstrating detection of snow.

- U.S. national network and research radar, disdrometer and gauge assets bridge point to satellite footprint scales, thus creating statistical validation datasets. Supplemental datasets (gauges, radars etc.) from other regions and international partners also used to help evaluate basic trends between products.

✓ L1 rain requirements demonstrated over the continental U.S. and two different ocean sites (tropical and high latitude) for GPM Version 4 and Version 5 products [exception GMI GPROF random error over continental U.S.].

✓ L1 DSD requirements satisfied for V4 and V5 algorithms. Shift in DSD behavior in V5 needs to be examined.

✓ L1 snow detection demonstrated and now expect stronger emphasis to be put on more robust estimation of SWER- possibly V6.

- GPM Version 5 products will be available by early May 2017 (see Erich Stocker, PPS, for details)

EXTRA

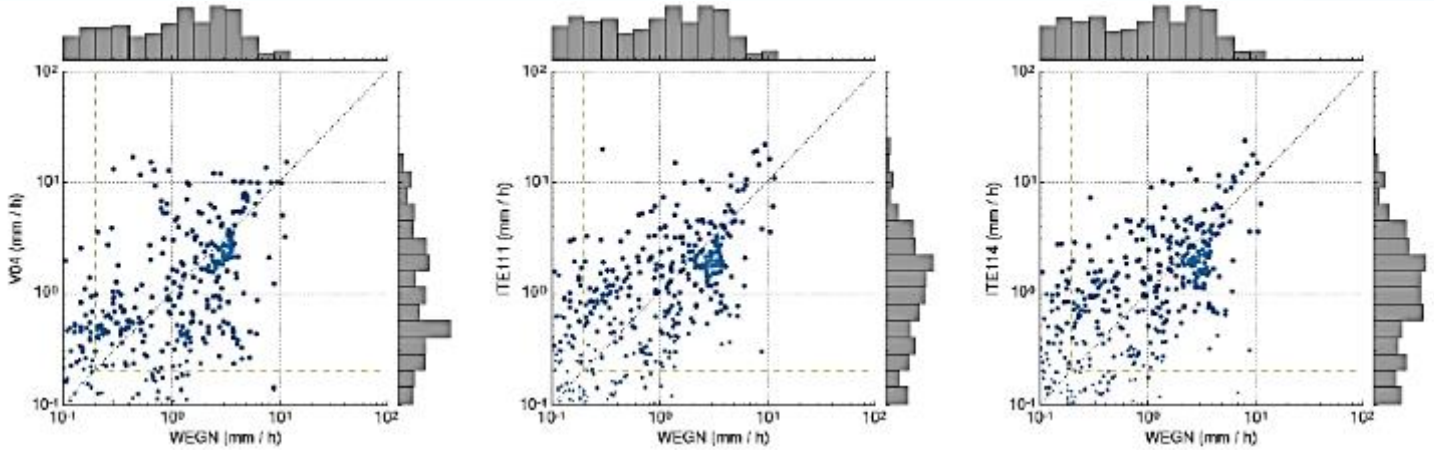
Rain Rate Footprints and Gauges: GPROF GMI V4 to ITE 114

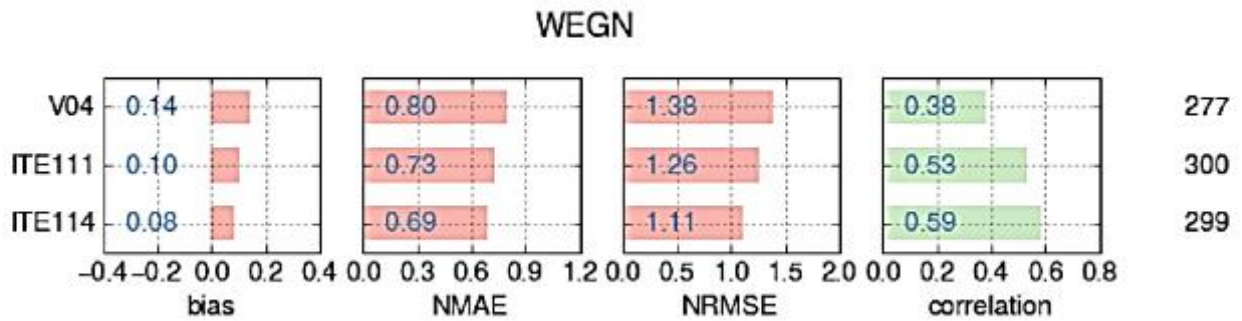
1 Gauge every ~ 1 km^2

Require: Minimum 12-gauges/15 km footprint, 15 minute accumulation

Example:
WegenerNet, Austria

V4 vs. GV | ITE111 vs. GV | ITE114 vs. GV



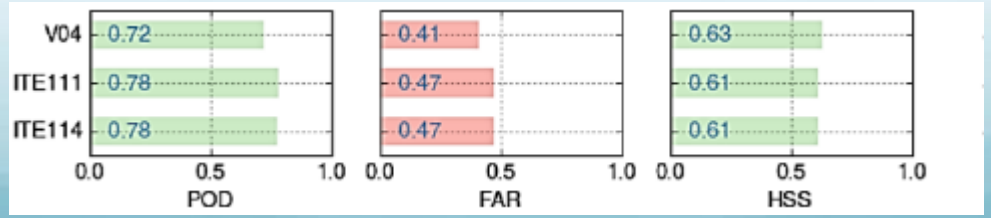


Intensity

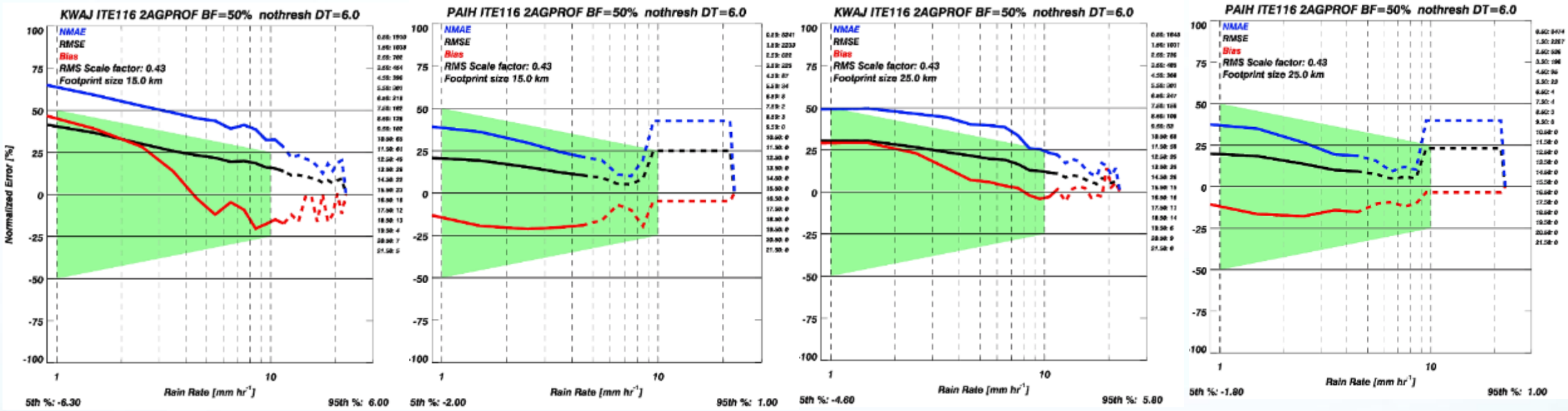
Good for tracking steady improvements in product.

….but low sample numbers at this stage of the mission impact scores……

Detection



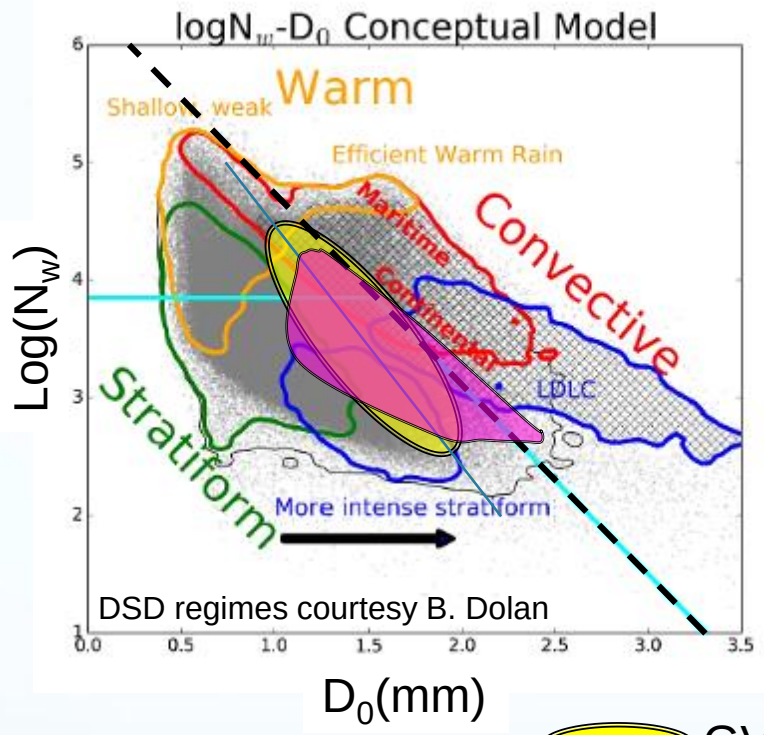
V5 GPROF GMI, and L1 **Rain Rate** vs. Ocean GV



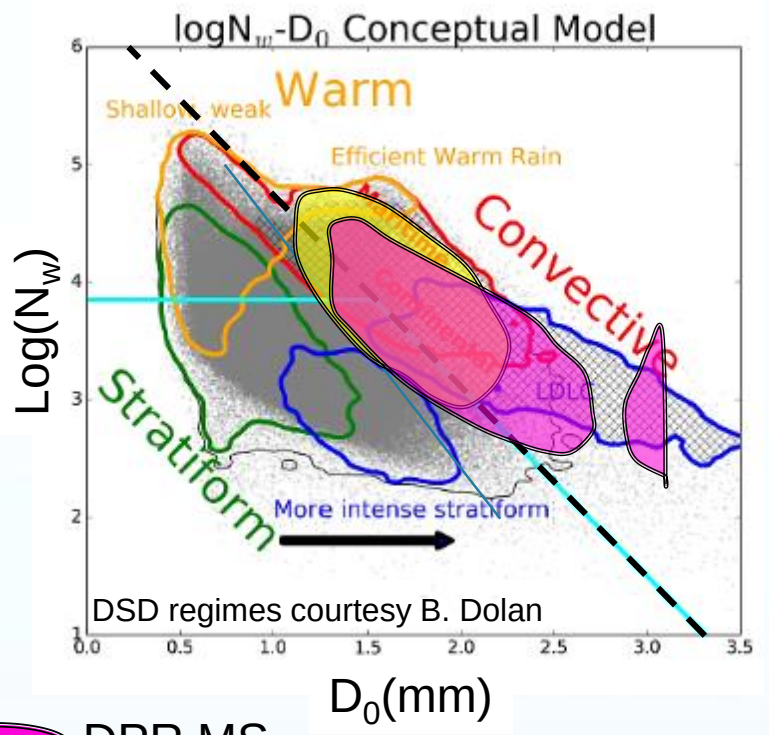
Bias and Random error at 15 km footprint scale are within L1 over Ocean sites and generally improve by going to a 25 km footprint- more consistent with true "effective" footprint of algorithm over ocean.

DSD: V5 DPR MS Convective D_m and N_w

GV 2DVD D_o vs N_w



GV 2DVD D_o vs N_w



GV DPR MS

- DPR MS V5 fits GV sample space (Assuming $D_m \approx D_0$); behavior is somewhat similar to GPM GV Radar
- Shift to larger D_m and smaller N_w relative to GV; secondary mode at large D_m
- Combined algorithm (not shown) also generally "fits" GV - but with different N_w-D_m slope behavior in stratiform